Optomagnetic characterization and detection: Inexpensive, fast and sensitive characterization of magnetic nanoparticles and detection of biomolecules

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Optomagnetic characterization and detection: Inexpensive, fast and sensitive characterization of magnetic nanoparticles and detection of biomolecules.

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Magnetic nanoparticles (MNPs) are important for a number of biomedical applications ranging from hyperthermia, magnetic resonance imaging to biodetection assays. We present the use of optomagnetic (OM) measurements to characterize the physical properties of MNPs, and for bio-sensing purposes.

OM sensing relies on measurements of the intensity modulation of light transmitted through a magnetic nanoparticle (MNP) suspension in response to an oscillating magnetic field, $B(t) = B_0 \sin(2\pi f t)$. Linked optical and magnetic anisotropies of MNPs or MNP aggregates produce a modulation of the transmitted light intensity due to a periodic physical reorientation induced by the applied magnetic field (Fig 1a). Although OM measurements may seem restricted to particular nanoparticle systems, we have found that surprisingly many commercially available particle systems show a significant OM signal and hence can be studied and used by this technique.

We demonstrate the use of OM measurements to find, the hydrodynamic volume (V_h) distribution from low-field measurements vs. frequency as well as the magnetic moment (m) distribution from low-frequency measurements vs. field amplitude [1]. As a unique and novel feature, we also show how the correlation between V_h and m can be found [2] (Fig. 1b) and how the correlation provides important information on the magnetic particle properties [3].

We also present the use of OM measurements for biodetection. The method is sensitive to changes of V_h resulting from binding or growth of biomolecules to individual MNPs or to analyte-induced clustering of MNPs. The method is particularly sensitive to clustering due to the sign change of the OM signal when aggregates have sizes comparable with the wavelength [4], [5]. We also demonstrate that magnetic incubation (cyclic application of a strong magnetic field) can significant reduce the assay time, thus overcoming the rate-limiting diffusion in conventional agglutination assays. This accelerated clustering makes iterative DNA hybridization-denaturing under changing conditions feasible [6].

We are currently working on integration of isothermal amplification schemes with optomagnetic detection, such as loop-mediated isothermal amplification [7], rolling circle amplification, and recombinase polymerase amplification, RPA (Fig. 2). RPA is especially promising due to the low amplification temperature and the stability and storage of reagents in dry format.

OM measurements can be realized in a fairly simple setup, which is suited to be used as readout in a low-cost disposable lab-on-a-chip system as the technique requires only a transparent sample container. The OM method is being commercialized by BluSense Diagnostics, who has developed the *BluBox* (Fig. 3) capable of performing OM measurements on a microfluidic disc platform. The first-line products of BluSense are one-drop-of-blood quantitative antigen and antibody tests that accurate diagnose dengue and zika. An RPA assay detecting E. Coli is currently under development and is aimed at the water sector for fast assessment of water quality.

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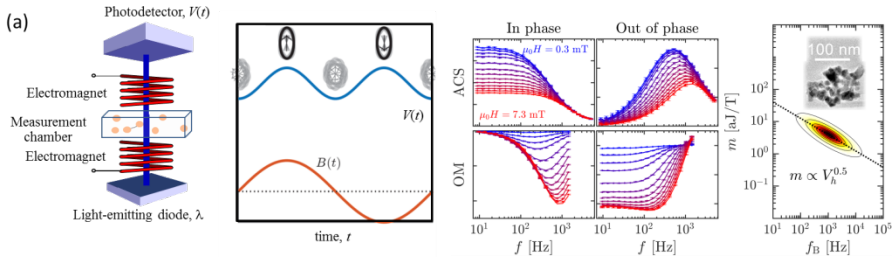

Figure 1. (a) Schematic and principle of OM measurement. (b) Simultaneous measurement of the AC susceptibility (ACS) and/or OM signals vs field and frequency are used to obtain the V_h and m correlation [2].

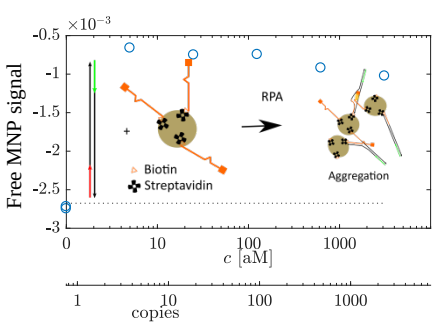

Figure 2. End-point optomagnetic E. Coli detection using recombinase polymerase amplification that provides a simple yes/no result.

Figure 3. BluBox from BluSense Diagnostics (www.blusense-diagnostics.com) performing optomagnetic readout of infectious diseases on a centrifugal microfluidic platform.